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SPECIFICATION

AIR SEPARATOR

TECHNICAL FIELD

The present invention relates to an air separator capable of producing oxygen gas in an energy-saving manner, thereby remarkable downsizing can be realized.

BACKGROUND ARTS

Generally, a nitrogen gas (GN_2), an oxygen gas (GO_2), argon (Ar) and the like are manufactured by the following steps. As shown in Fig. 6, air is used as a raw material and is compressed by an air compressor 61 and the thus compressed air is put into adsorption towers 62 for eliminating water (H_2O), carbon dioxide gas (CO_2) and hydrocarbon gas (C_nM_m) from the compressed air by means of adsorption. Further, the thus obtained gas is passed through a main heat exchanger (not shown) in a cold box 63 so as to be cooled to a super low temperature by heat-exchanging with refrigerant. Then, product gas (such as nitrogen gas or oxygen gas) is manufactured by cryogenically separating the thus cooled gas in a rectification tower (not shown) and is passed through the main heat exchanger, so that the temperature of the product gas is increased nearly to ambient temperature. An exhaust gas withdrawn from the cold box 63 is used for regenerating the adsorption towers 62 (see, for example,

Japanese Unexamined Patent Publication No. 8-261644). In Fig. 6, a reference numeral 64 indicates a heater for regeneration and evacuation.

In such an air separator, an air compressor 61 having a discharge pressure of about 5kg/cm^{2}G (0.5MPaG (gauge pressure)) is generally used. The amount of air required for manufacturing oxygen gas of 10,000m^3/h (Normal) by using such an air compressor 61 is calculated as follows. Each rate (% by volume) of elements of air, that is, oxygen, nitrogen and argon, is 20.9%, 78.1% and 0.9%, respectively. When recovery efficiency of oxygen gas is 97%, the amount of air is theoretically calculated by the formula of $(10{,}000 \div 0.209) \div 0.97$. As a result, about 50,000m^3/h (Normal) is determined as the air required. Therefore, the size of each of the adsorption towers 62, the main heat exchanger, the rectification tower and the like should be enlarged correspondingly for such an amount of air, which makes the apparatus large-sized as a whole. Further, when oxygen gas of 10,000m^3/h (Normal) is produced, the power required for working the air compressor 61 is about 4500kW (power required for compression is generally considered to be equal to a value found by multiplying the required amount of air by about 0.09), and the power required for working the heater 64 for regeneration and evacuation of the adsorption towers 62 is about 500kW. In total, a great amount of power of about 5000kW is required, which means a significant energy required

for manufacturing oxygen.

The present invention is made in view of such circumstances and it is an object of the invention to provide an air separator capable of manufacturing oxygen gas in an energy-saving manner and that enables cryogenic separation mechanism and the like (a cold box and interior devices therein) to be remarkably downsized.

DISCLOSURE OF THE INVENTION

In accordance with the present invention to achieve the aforesaid object, there is provided an air separator including an air compression means for taking in air from the outside and compressing it at a low pressure, an oxygen concentrating means for concentrating oxygen gas that is contained in the air compressed by the air compression means, an oxygen/air compression means for further compressing oxygen-rich compressed air (X), which has passed through the oxygen concentrating means, a heat exchanger for cooling oxygen-rich compressed air (Y), which has passed through the oxygen/air compression means, and a rectification tower for taking out oxygen gas by separating the oxygen-rich compressed air (Y), which has passed through the heat exchanger so as to be cooled to a low temperature, by utilizing differences in boiling points of elemental gases.

According to the air separator of the present invention, raw-material air is compressed at a low pressure by an air

compression means, the concentration of oxygen in the raw-material air is increased by an oxygen concentrating means, following the air compression means, for concentrating oxygen gas in the thus compressed air, the thus obtained gas is passed through an oxygen/air compression means and a heat exchanger, and then is supplied to a rectification tower. For this reason, in the case where the same amount of oxygen gas or the like is produced, energy can be greatly saved and also the amount of gas to be circulated through each means following the oxygen concentrating means can be reduced, so that each means can be downsized to a half size or less, which enables remarkable downsizing of the entire apparatus. In the present invention, "low pressure" in the above-mentioned context means a pressure lower than the compression pressure caused by the oxygen/air compression means, and means generally not more than one-third, preferably not more than one-fifth, and more preferably not more than one-tenth of the compression pressure by the oxygen/air compression means.

Where the oxygen concentrating means is an adsorption tower accommodating an adsorbent for adsorbing nitrogen gas in the compressed air and impurities such as moisture in the compressed air are adsorbed by the adsorbent, the oxygen gas in the compressed air can be concentrated by the action of the adsorbent of the adsorption tower and also moisture in the compressed air can be eliminated so that the resultant gas to

be compressed by the oxygen/air compression means following the oxygen concentrating means becomes drier and thus power for compression can further be reduced.

Where an elimination means for eliminating impurities in the oxygen-rich compressed air (Y) is provided between the oxygen/air compression means and the heat exchanger, hydrocarbon, moisture, NO_x and the like slightly remaining in the oxygen-rich compressed air (Y) can be eliminated, so that poor-quality air such as air in coastal areas (containing many sodium ions) and air alongside a street (containing much automotive exhaust gas) can be used as a raw-material air.

Where a part of the air compressed by the air compression means is not passed through the oxygen concentrating means, but is supplied directly to an inlet path for introducing the oxygen-rich compressed air (X) passed through the oxygen concentrating means into the oxygen/air compression means, the part of the compressed air directly supplied to the inlet path (after having passed through the air compression means) is allowed to merge into the remaining part of the compressed air supplied to the inlet path (after having passed through the air compression means and introduced into the oxygen concentrating means so as to become the oxygen-rich compressed air (X)), thereby the concentration of oxygen in the oxygen-rich compressed air (X) can be lowered. Therefore, when the amount of oxygen to be manufactured needs to be reduced, it can be

realized by adjusting the amount of the compressed air directly supplied to the inlet path.

BRIEF DESCRIPTION OF DRAWING

Fig. 1 is a block diagram of one embodiment of an air separator according to the present invention;

Fig. 2 is a block diagram of another embodiment of an air separator according to the present invention;

Fig. 3 is a block diagram of a further embodiment of an air separator according to the present invention;

Fig. 4 is a block diagram of a still further embodiment of an air separator according to the present invention;

Fig. 5 is a block diagram of a still further embodiment of an air separator according to the present invention; and

Fig. 6 is a block diagram of a conventional example.

BEST MODE FOR CARRYING OUT THE INVENTION

Fig. 1 is a block diagram of one embodiment of an air separator according to the present invention. In Fig. 1, a reference numeral 1 indicates an air compressor (air compression means) for taking in air and compressing it, wherein a discharge pressure is low and about 0.1kg/cm^{2}G (0.01MPaG (gauge pressure)). A reference numeral 1a indicates a first feeding pipe for feeding compressed air passed through the air compressor 1 into first adsorption towers 2, 3. The first adsorption towers (oxygen concentration means) 2, 3, are filled with an adsorbent such as silica gel at an upstream side thereof,

and they are also filled with a molecular sieve adsorbent developed by the present applicant (AW0203 available from Air Water Inc.) at a downstream side. The first adsorption towers 2, 3 are aligned in pairs and one of them works for adsorption while the other works for regeneration, alternately. In this embodiment, by means of the action of the adsorbent of the first adsorption towers 2, 3 (nitrogen adsorption process), the amount (% by volume) of each of the components of the low-pressure compressed air passed through the air compressor 1 is arranged, for example, in such a manner that oxygen gas is about 50%, nitrogen gas is about 47.5% and argon gas is about 2.5%, respectively. The concentration of the oxygen gas in the compressed air is increased from 20.9% by volume to 50% by volume. The adsorption towers 2, 3 also eliminates water (H_2O), carbon dioxide gas (CO_2), hydrocarbon gas (C_nM_m) and the like from the compressed air by the action of the adsorbent, simultaneously with the above-mentioned increase in oxygen concentration. A reference numeral 4 indicates a vacuum pump for regeneration and evacuation of the first adsorption towers 2, 3, and a reference numeral 4a indicates a first release pipe for releasing exhaust gas adsorbed by the adsorbent of the first adsorption towers 2, 3 into the atmosphere and regenerating the adsorbent. In this way, the system composed of the first adsorption towers 2, 3, and their pipes provided with open-close valves 6a, 6b and 8a, 8b, respectively, and the vacuum

pump 4 is a VSA (Vacuum Swing Absorbed) system, which is a membrane separation system, so that one adsorption tower 2 (3) works for adsorption while the other tower 3 (2) is regenerated by means of vacuum suction by the vacuum pump 4. Further, a water separator (not shown) may be provided between the air compressor 1 and the first adsorption towers 2, 3 for eliminating moisture from the compressed air compressed by the air compressor, and, as required, a flon cooler (not shown) for cooling the compressed air passed through the water separator may be provided. In this embodiment, the above-mentioned system is a VSA system, however, it may be a membrane separation system such as a PSA (Pressure Swing Absorbed) system or a TSA (Thermal Swing Absorbed) system. In Fig. 1, reference numerals 6a, 6b, 7a, 7b, 8a and 8b are open-close valves for conducting adsorption or regeneration of the first adsorption towers 2, 3, alternately.

A reference numeral 11 indicates a compact oxygen/air compressor (oxygen/air compression means) for further compressing the oxygen-rich compressed air (X) passed through the first adsorption towers 2, 3. (As the amount of gas to be circulated through the oxygen/air compressor can be halved as compared with the conventional type, the oxygen/air compressor can be downsized to a half size or less.) In this embodiment, a compact oxygen/air compressor (oilless centrifugal compressor having a discharge pressure of 5kg/cm^{2}G (0.5MPaG

(gauge pressure)) for further compressing the oxygen-rich compressed air (X) is used as the compact oxygen/air compressor 11. The oxygen/air compressor 11 is an oilless mechanism to prevent explosion in further compressing the oxygen-rich compressed air (X). A reference numeral 11a indicates a second feeding pipe for feeding the oxygen-rich compressed air (Y) passed through the oxygen/air compressor 11 to second adsorption towers 12, 13. The adsorption towers 12, 13, each filled with an adsorbent such as a commercially available molecular sieve, are aligned in pairs and one of them works for adsorption while the other works for regeneration, alternately (and is a compact size of half or less as compared with the conventional type) for eliminating water (H_2O), carbon dioxide gas, C_nM_m, NO_x and the like slightly remaining in the oxygen-rich compressed air (Y) further compressed by the oxygen/air compressor 11. A reference numeral 14 indicates a second release pipe for releasing exhaust gas, which has finished the regeneration process in the second adsorption towers 12, 13, into the atmosphere. The system composed of the second adsorption towers 12, 13, and their pipes provided with open-close valves 16a, 16b and 19a, 19b, respectively, is a TSA system. In Fig. 1, reference numerals 16a, 16b, 17a, 17b, 18a, 18b, 19a and 19b are open-close valves for conducting adsorption or regeneration of the second adsorption towers 12, 13, alternately.

A reference numeral 21 indicates a main heat exchanger such as a plate-fin exchanger, which cools the oxygen-rich compressed air (Y), wherein minute amounts of water, carbon dioxide gas and the like remaining are eliminated by means of adsorption by adsorption towers 12, 13, to a super low temperature. As the amount of gas to be circulated through the main heat exchanger 21 to be processed therein can also be halved as compared with the conventional type, the main heat exchanger can be downsized to a half size or less. A reference numeral 22 indicates a supply pipe for supplying the oxygen-rich compressed air (Y) cooled to a super low temperature by the main heat exchanger 21 into a lower part of a high-pressure rectification tower 23. As the amount of gas to be circulated through the high-pressure rectification tower (a column plate type or a packed column type) 23 can be halved as compared with that of the conventional type, the half or less capacity of the high-pressure rectification tower is enough and thus the size thereof can be downsized to half or less. In the high-pressure rectification tower 23, liquid oxygen-rich liquid air 24 of the oxygen-rich compressed air (Y) fed through the supply pipe 22 accumulates in the bottom portion, while nitrogen gas rises. A part of the rising nitrogen gas is passed through a first reflux pipe 31 and introduced into a condenser 30 positioned in a lower portion of a low-pressure rectification tower 28, while the remaining part thereof is passed through a nitrogen takeout pipe

26 and activates an expansion turbine 37. The nitrogen gas introduced into the condenser 30 is liquefied so as to become liquid nitrogen. The nitrogen gas thus liquefied is returned through a second reflux pipe 32 to an upper portion of the high-pressure rectification tower 23 as a reflux liquid, and flows downward in the high-pressure rectification tower 23, and then contacts in a countercurrent manner the oxygen-rich compressed air (Y) rising from the bottom, thereby liquefying a high-boiling point elemental gas (oxygen gas) in the oxygen-rich compressed air (Y), which flows downward. For this reason, the liquid oxygen-rich liquid air 24 is accumulated in the bottom so as to be further oxygen-rich, while a low-boiling elemental gas (nitrogen gas) rises upward in the high-pressure rectification tower 23. The nitrogen gas withdrawn through the nitrogen takeout pipe 26 is supplied to the main heat exchanger 21 so as to cool compressed air passed through the main heat exchanger 21, and is supplied through a first connecting pipe 26a to an expansion turbine 37 so as to be a driving source for the expansion turbine 37, as mentioned above, to generate cold. A reference numeral 38 indicates a bypass provided with an open-close valve 38a. In other words, the nitrogen gas introduced through the nitrogen takeout pipe 26 and the first connecting pipe 26a provided with the open-close valve 26b into the expansion turbine 37 expands therein and conducts thermodynamic external work, so that the nitrogen gas is cooled

to an extremely low temperature to generate cold in an amount required for the air separator. The nitrogen gas in such a state is supplied through a second connecting pipe 37a into the main heat exchanger 21 wherein the nitrogen gas itself becomes ambient temperature by heat exchanging with a raw material air for imparting the cold to the raw material air. Most of such nitrogen gas is passed through a release pipe 37b and is released into the atmosphere as an exhaust gas, while a part thereof is passed through a branch pipe 40 so as to regenerate an adsorbent of the second adsorption towers 12, 13. The branch pipe 40 functions for supplying the introduced nitrogen gas into either a first pipe 42 provided with a heater 41 or a second pipe 43 without a heater. A reference numeral 44 indicates a third pipe for supplying nitrogen gas passed through the first pipe 42 or the second pipe 43 into the second adsorption towers 12, 13 for regenerating the adsorbent.

A reference numeral 28 indicates a low-pressure rectification tower (a column plate type or a packed column type) located above the high-pressure rectification tower 23. The liquid oxygen-rich liquid air 24 accumulated in the bottom of the high-pressure rectification tower 23 is fed through a feeding pipe 29 provided with an expansion valve 29a into the low-pressure rectification tower 28. The low-pressure rectification tower 28 contains the condenser 30 in the bottom thereof into which a part of nitrogen gas withdrawn from the

high-pressure rectification tower 23 is introduced through the first reflux pipe 31. The thus withdrawn nitrogen gas heats liquid oxygen 34 (LO_2: purity of about 99.7% by volume) accumulated in the bottom of the low-pressure rectification tower 28 so as to be evaporated while the nitrogen itself liquefies due to coldness of the liquid oxygen 34 and a part thereof is returned through the second reflux pipe 32 provided with a flow adjusting valve 32a to the upper part of the high-pressure rectification tower 23 as a reflux liquid, as mentioned above. The remaining part of the liquid nitrogen 34 is introduced through a branch pipe 33 provided with a flow adjusting valve 33a into the upper part of the low-pressure rectification tower 28 as a reflux liquid and flows down through the low-pressure rectification tower 28 for gas-liquid separation. A reference numeral 35 indicates a product oxygen gas takeout pipe extended from the lower part of the low-pressure rectification tower 28. The product oxygen gas takeout pipe 35 takes out high-purity oxygen gas evaporated from the liquid oxygen 34 accumulated in the bottom of the low-pressure rectification tower 28 and feeds the thus withdrawn oxygen gas to the main heat exchanger 21 for heat-exchange with the oxygen-rich compressed air (Y) so that the oxygen gas itself becomes ambient temperature and then is released to the outside of the apparatus as product oxygen. A reference numeral 36 indicates a product nitrogen gas takeout pipe extended from the

upper part of the low-pressure rectification tower 28. The product nitrogen gas takeout pipe 36 takes out nitrogen gas rising upwards in the low-pressure rectification tower 28 and feeds the thus withdrawn nitrogen gas to the main heat exchanger 21 for cooling the oxygen-rich compressed air (Y), so that the nitrogen gas itself becomes ambient temperature and then is released to the outside of the apparatus as product nitrogen gas. A reference numeral 39 is a cold box into which heat insulating material such as perlite (not shown) is packed for low-temperature insulation. In this embodiment, oxygen is concentrated by adsorbing nitrogen gas in the first adsorption towers 2, 3, however, an adsorbent for adsorbing oxygen gas may be used, so that oxygen gas may be adsorbed, and the thus obtained oxygen gas is concentrated, and then withdrawn.

The nitrogen gas and the oxygen gas are manufactured by using this apparatus in the following manner. That is, air is taken into the air compressor (air compression means) 1 from the outside so as to be compressed at a low pressure, and moisture in the compressed air is eliminated by the water separator (not shown), and then the air in such a state is fed into the first adsorption towers (oxygen concentrating means) 2, 3, so that nitrogen gas, moisture, carbon dioxide gas, hydrocarbon gas (C_nM_m) and the like from the compressed air are eliminated by means of adsorption, thereby oxygen gas in the compressed air is concentrated, which is a main feature of the present

invention. In turn, the oxygen-rich compressed air (X) from the first adsorption towers 2, 3 is introduced into the oxygen/air compressor (oxygen/air compression means) 11 for further compressing the oxygen-rich compressed air (X) for obtaining the oxygen-rich compressed air (Y). The oxygen-rich compressed air (Y) is fed into the second adsorption towers 12, 13 for eliminating water, carbon dioxide gas, NO_x and the like in the oxygen-rich compressed air (Y). Successively, the oxygen-rich compressed air (Y), from which water, carbon dioxide gas, NO_x and the like have been eliminated by adsorption, is fed into the main heat exchanger 21 so as to be cooled to a super low temperature, and is introduced into the lower part of the high-pressure rectification tower 23 in such a state. In the high-pressure rectification tower 23, the oxygen-rich compressed air (Y) is brought into contact with reflux liquid produced in the low-pressure rectification tower 28 in a countercurrent manner for purifying the compressed air, thereby liquefying a high-boiling point elemental gas (oxygen gas) in the oxygen-rich compressed air (Y), thereby leaving nitrogen in a gaseous state by using the difference in boiling point between nitrogen and oxygen (boiling point for oxygen of −183℃, that for nitrogen of −196℃). The nitrogen gas is withdrawn through the nitrogen takeout pipe 26, and is supplied to the main heat exchanger 21, and then is supplied to the expansion turbine 37 so as to generate cold. Most of such nitrogen gas

is released to the outside of the apparatus while a part thereof is used for regenerating the second adsorption towers 12, 13.

Then nitrogen gas accumulated in the upper part of the low-pressure rectification tower 28 is taken out through the product nitrogen gas takeout pipe 36 is fed into the main heat exchanger 21 so as to be heated nearly to the ambient temperature, and then released to the outside of the apparatus as product nitrogen gas. On the other hand, the liquid oxygen-rich liquid air 24 accumulated in the bottom of the high-pressure rectification tower 23 is fed through a feeding pipe 29 into the low-pressure rectification tower 28, and liquid oxygen 34, wherein nitrogen has been evaporated and eliminated, is accumulated in the bottom of the low-pressure rectification tower 28 and is heat exchanged with nitrogen gas passed through the condenser 30 positioned in the bottom of the low-pressure rectification tower 28 so as to be evaporated. The thus evaporated oxygen gas is withdrawn through the product gas takeout pipe 35, and is fed into the main heat exchanger 21 so as to be heated nearly to the ambient temperature, and then is released to the outside of the apparatus as a product oxygen gas. Thus, product oxygen gas and product nitrogen gas can be obtained.

In this embodiment, the concentration of oxygen in the compressed air is increased from 20.9% by volume to about 50% by volume by the first adsorption towers 2, 3. The amount of

air required for manufacturing oxygen gas of 10,000m^3/h (Normal) is calculated as follows. When recovery efficiency of oxygen gas is 97%, the amount of air is theoretically calculated by the formula of $(10{,}000 \div 0.500) \div 0.97$. As a result, about 20,600m^3/h (Normal) is determined as the air required, which is reduced to about 41% as compared with that required in the conventional apparatus mentioned at the beginning of the present specification. Further, when oxygen gas of 10,000m^3/h (Normal) is produced, the power required for working the oxygen/air compressor 11 is reduced to about 2000kW, and it is thought that the power required for working the oxygen/air compressor 1 is about 300kW, the power required for working the vacuum pump 4 is about 900kW, and the electrical power for the electrical heater 41 is about 200kW. The total amount is about 3400kW, reduced to about 70% as compared with the conventional apparatus. Therefore, energy can be saved by 30% or more.

Further, in this embodiment, the first adsorption towers 2, 3 are provided for increasing the concentration of the oxygen gas in the compressed air obtained by compressing air as raw material by the air compressor 1. The thus obtained gas is fed through the oxygen/air compressor 11 and the main heat exchanger 21 into the high-pressure rectification tower 23 and the low-pressure rectification tower 28. For this reason, the amount of gas to be circulated through each device such as the main heat exchanger 21 and both of the rectification towers 23,

28 following the oxygen/air compressor 11, can be reduced, so that each device can be downsized to a half size or less, which enables remarkable downsizing of the entire apparatus.

For example, when oxygen gas of 70,000m^3/h (Normal) is produced, the high-pressure rectification tower 23 has a diameter of 7m in the conventional apparatus (according to the calculated value by the applicant). Since there is no means for transporting such a high-pressure rectification tower, there is no choice but to assemble it on site. However, when the same amount of oxygen gas is produced in this embodiment, the amount of gas to be circulated through the rectification tower can be halved, so that the diameter of the rectification tower can be reduced to about 4.2m. For this reason, it is possible to transport the rectification tower assembled in a plant to a site, resulting in great laborsaving.

Fig. 2 illustrates another embodiment of an air separator according to the present invention. In this embodiment, second adsorption towers 12, 13 are eliminated. In other words, second adsorption towers 12, 13, a second release pipe 14, pipes provided with open-close valves 16a, 16b, 17a, 17b, 18a, 18b, 19a and 19b, a branch pipe 40, first to third pipes 42 to 44 are eliminated. Except for that, this embodiment is the same as the above-mentioned embodiment and similar parts are denoted by the same reference numerals. When the apparatus of this embodiment is installed in the place where clean air is used

as a raw material, the same effects as in the above-mentioned embodiment can be obtained and also the apparatus can be simplified and downsized.

Fig. 3 illustrates a further embodiment of an air separator according to the present invention. In this embodiment, a liquid oxygen tank (not shown) into which liquid oxygen (LO_2) is supplied from the outside of the apparatus by means of a tanker or the like is used instead of an expansion turbine 37 in the embodiment as shown in Fig. 2. Except that such liquid oxygen is used as a cold source, this embodiment is substantially the same as that shown in Fig. 2. In Fig. 3, a reference numeral 47 indicates an inlet pipe for introducing the liquid oxygen from the liquid oxygen tank into the lower part of a low-pressure rectification tower 28 as a cold source. The liquid oxygen introduced by the inlet pipe 47 flows downward to the bottom of the low-pressure rectification tower 28 and joins liquid oxygen 34 accumulated in the bottom thereof. A reference numeral 48 indicates an exhaust pipe extended from the low-pressure rectification tower 28 for withdrawing nitrogen gas (exhaust GN_2) accumulated in the upper part of each shelf (or packed column) of the low-pressure rectification tower 28 so as to be introduced into a supercooler 49. The exhaust pipe 48 leads the exhaust nitrogen gas passed through the supercooler 49 into a main heat exchanger 21 for cooling the oxygen-rich compressed air (Y) and releases the exhaust

nitrogen gas to the outside. The supercooler 49, through which are passed: a) oxygen-rich liquid air 24 via a feeding pipe 29; b) liquid nitrogen (reflux liquid) via a branch pipe 33; c) product nitrogen gas via a product nitrogen gas takeout pipe 36; and d) exhaust nitrogen gas via the exhaust pipe 48, works for cooling the oxygen-rich liquid air 24 a). A reference numeral 50 indicates a liquid oxygen takeout pipe extended from the bottom of the low-pressure rectification tower 28. The liquid oxygen takeout pipe 50 takes out liquid oxygen accumulated in the bottom of the low-pressure rectification tower 28, which is led into the main heat exchanger 21 for cooling the oxygen-rich compressed air (Y), and also heating the liquid oxygen itself up to ambient temperature for obtaining product oxygen gas, and introduces the thus obtained product oxygen gas into a product oxygen gas takeout pipe 35. A reference numeral 51 indicates a product nitrogen gas compressor installed in a product nitrogen takeout pipe 36 for increasing the pressure of the product nitrogen gas passing through the product nitrogen gas takeout pipe 36 to a specified pressure. A reference numeral 52 indicates a first product oxygen gas compressor installed in the product oxygen gas takeout pipe 35 for increasing the pressure of the product oxygen gas passing through the product oxygen gas takeout pipe 35 to a specified pressure and feeding the product oxygen gas into a low pressure product oxygen gas takeout pipe 53. A reference numeral 54

indicates a second product oxygen gas compressor for further increasing the pressure of the product oxygen gas passed through the first product oxygen gas compressor 52 and feeding the product oxygen gas into a high pressure product oxygen gas takeout pipe 55. In this embodiment, the ceiling of the high-pressure rectification tower 23 and the bottom of the low-pressure rectification tower 28 located above the high-pressure rectification tower 23 are formed integrally by the same material. In Fig. 3, a reference numeral 36a indicates a pipe for feeding a product nitrogen gas passing through the product nitrogen takeout pipe 36 into an exhaust pipe 48. A reference numeral 39A is a cold box in which an insulating material such as perlite is filled and vacuum sucked. Except for that, this embodiment is the same as that shown in Fig. 2 and similar parts are denoted by the same reference numerals.

The nitrogen gas and the oxygen gas are manufactured by using this apparatus in the following manner. That is, in the same manner as in the embodiment as shown in Fig. 2, air is taken into the air compressor (air compression means) 1 from the outside in which air is compressed at a low pressure, and moisture in the compressed air is eliminated by the water separator (not shown), and then the air in such a state is fed into the first adsorption towers (oxygen concentrating means) 2, 3, so that nitrogen gas, moisture, carbon dioxide gas, hydrocarbon gas (C_nM_m) and the like in the compressed air are

eliminated by means of adsorption, thereby the concentration of oxygen gas in the compressed air is increased. In turn, the oxygen-rich compressed air (X) from the first adsorption towers 2, 3 is introduced into the oxygen/air compressor (oxygen/air compression means) 11 for further compressing the oxygen-rich compressed air (X) for obtaining the oxygen-rich compressed air (Y). The oxygen-rich compressed air (Y) is fed into the main heat exchanger 21 to be cooled to a super low temperature and is introduced into a lower part of a high-pressure rectification tower 23 in such a state. In the high-pressure rectification tower 23, the oxygen-rich compressed air (Y) is brought into contact with reflux liquid produced in the low-pressure rectification tower 28 in a countercurrent manner for purifying the compressed air, thereby liquefying a high-boiling point elemental gas (oxygen gas) in the oxygen-rich compressed air (Y), thereby leaving nitrogen in a gaseous state by using the difference in boiling point between nitrogen and oxygen (boiling point for oxygen of -183℃, that for nitrogen of -196℃).

Then, nitrogen gas accumulated in the upper part of the low-pressure rectification tower 28 is taken out through the product nitrogen gas takeout pipe 36, and is fed into the supercooler (heat exchanger) 49, and then is fed into the main heat exchanger 21 so as to be heated nearly to the ambient temperature, and finally is released to the outside of the

apparatus as product nitrogen gas. On the other hand, the oxygen-rich liquid air 24 accumulated in the bottom of the high-pressure rectification tower 23 is fed through a feeding pipe 29 into the supercooler 49 so as to be cooled. The oxygen-rich liquid air 24 in a gas-liquid mixing state is fed into the low-pressure rectification tower 28, wherein nitrogen has been evaporated and eliminated, so that liquid oxygen 34 is accumulated in the bottom of the low-pressure rectification tower 28 and is heat exchanged with nitrogen gas passed through the condenser 30 positioned in the bottom of the low-pressure rectification tower 28 so as to be evaporated. The thus evaporated oxygen gas is withdrawn through the product oxygen gas takeout pipe 35, and is fed into the main heat exchanger 21 so as to be heated nearly to the ambient temperature, and then is released through a low-pressure product oxygen gas takeout pipe 53 via a first product oxygen gas compressor 52 to the outside of the apparatus as product oxygen gas and is also released through a high-pressure product oxygen takeout pipe 55 via a second product oxygen gas compressor 54 to the outside of the apparatus as product oxygen gas. Thus, the product oxygen gas and the product nitrogen gas can be obtained.

As mentioned above, the same effects and advantages are obtained in this embodiment as well as in the embodiment as shown in Fig. 2.

Fig. 4 illustrates a still further embodiment of an air

separator according to the present invention. In this embodiment, a liquid nitrogen tank (not shown) into which liquid nitrogen (LN_2) is supplied from the outside of the apparatus by means of a tanker or the like is used instead of an expansion turbine 37 in the embodiment as shown in Fig. 2. Except that such liquid nitrogen is used as a cold source, this embodiment is substantially the same as that shown in Fig. 2. In Fig. 4, a reference numeral 47a indicates an inlet pipe for introducing the liquid nitrogen from the liquid nitrogen tank into the upper part of a high-pressure rectification tower 23 as a cold source. The liquid nitrogen introduced through the inlet pipe 47a and a part of the liquid nitrogen liquefied in a condenser 30 positioned in a lower part of a low-pressure rectification tower 28 are introduced into an upper part of the high-pressure rectification tower 23. Except for that, this embodiment is the same as that shown in Fig. 2 and similar parts are denoted by the same reference numerals.

Fig. 5 illustrates a still further embodiment of an air separator according to the present invention. In this embodiment, the first feeding pipe 1a for feeding the compressed air which has passed through the air compressor 1 into first adsorption towers 2, 3 and an inlet pipe 57 (a reference numeral 57 is not denoted in Fig. 1) for introducing the oxygen-rich compressed air (X), which has passed through the first adsorption towers 2, 3, into the oxygen/air compressor 11 (as

in the embodiment as shown in Fig. 1) are connected with a connecting pipe 58 provided with an open-close valve (or a flow adjusting valve) 58a. A part of the compressed air which has passed through the air compressor 1 and a water separator (not shown) is fed directly through the connecting pipe 58 into the inlet pipe 57 by opening the open-close valve 58a (i.e., instead of being passed through the adsorption towers 2, 3), and the remaining part is passed through the adsorption towers 2, 3 and introduced into the inlet pipe 57, so that both are allowed to join in the inlet pipe 57. Thus, the concentration of the oxygen gas of the remaining part of the compressed air introduced through the first adsorption towers 2, 3 into the inlet pipe 57 is diluted with the part of the compressed air introduced through the connecting pipe 58 into the inlet pipe 57. Except for that, this embodiment is the same as that shown in Fig. 1 and similar parts are denoted by the same reference numerals. The same effects and advantages are obtained in this embodiment as well as in the embodiment as shown in Fig. 1. Further, since the concentration of the oxygen gas in the compressed air supplied into the lower part of the high-pressure rectification tower 23 is lowered, the amount of the product oxygen gas can be reduced. Therefore, when the amount of the product oxygen gas is needed to be reduced, this embodiment enables to reduce it, correspondingly. Such a connecting pipe 58 provided with an open-close valve 58a can be used in the embodiments as shown

in Fig. 2 to Fig. 4.